Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

CONTRIBUTIONS FROM THE JEFFERSON PHYSICAL LABORATORY, HARVARD UNIVERSITY.

LONGITUDINAL MAGNETIC FIELD AND THE CATHODE RAYS.

By John Trowbridge.

Presented December 11, 1907. Received January 6, 1908.

In a previous article on the Magnetic Field and Electric Discharges[1] I described various phenomena which occur under the effect of a longitudinal field, both at the anode and the cathode. The present article deals with the effects of the field on the cathode rays after they have passed into the region beyond the anode. The form of tube which contained the rarefied gas was similiar to that generally employed to study the canal rays : a cylindrical tube with a concave aluminium cathode, an iron anode with an orifice at its centre, and a prolongation of the cylindrical tube behind the anode. Two exactly similiar tubes of this form, equal in size, were connected by the same adjunct to the exhausting pump, and were, therefore, under the same pressure.

In one of these tubes (Figure 1) the back of the anode, or iron terminal, was completely shielded from the prolongation of the tube in which canal rays are usually studied. A glass tube passed through the orifice in the iron terminal and was welded to the walls of the prolonged larger tube. No rays could enter the canal ray region except through the orifice in the iron terminal. In the companion tube the back of the terminal was not protected, and rays could pass over the periphery of the iron terminal and also through the orifice at the centre of the terminal.

It was found that the tube (Figure 1) apparently reached a much higher state of exhaustion than the companion tube, which I shall call B, although they were connected by the same large adjunct to the pump and, therefore, there could be no question of slow transpiration. One tube, A, was close to the X-ray stage, while B was hardly beyond the stratification stage.

I replaced these tubes by two spherical bulbs (Figure 2) similiar to those commonly employed as X-ray tubes ; these tubes also had prolongations, or canal regions, similiar to those of the previously mentioned cylindrical tubes. In one, A, the back of the terminal was protected as in Figure 1; in the other, B, the back was not protected. The same phenomenon was observed. Tube A came up nearly to the X-ray stage, while the other was apparently far below this stage.

---

[1] These Proceedings, **28**.

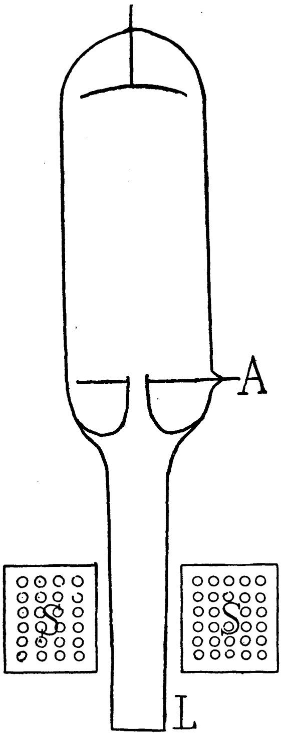

Figure 1.

Figure 2 is a photograph of the state of the two tubes. It is evident that the mere appearance of the discharge between the terminals is no criterion of the state of exhaustion unless one carefully considers the forms of the tubes and the extent of wall surface submitted to the bombardment of the cathode rays. The difference which I describe is probably due to the walls of the prolongation of the vacuum tubes, A being more protected from this bombardment than those of tubes B.

The forms A apparently showed the canal rays as perfectly as the forms B, when the iron terminal was made the cathode; and these rays did not seem to be modified by the protection of the edges of the orifice in the iron tube by the glass tube. The canal rays, therefore, come entirely from the space between the anode and the cathode.

A solenoid (S, Figure 1) was next slipped over the prolongation of the tubes. This prolongation, therefore, formed the core of the solenoid, and the rays passing through the orifice in the terminal could be submitted to a longitudinal magnetic field. By a proper adjustment of the position of the solenoid the cathode beam passing through the orifice in the iron terminal or the anode could be brought to a sharp focus on the end of the prolongation tube. This was also the case in tube B; but in the latter there was also a phosphorescent ring surrounding the focus of the central beam which was due to bringing to a focus the rays which passed over the periphery of the circular iron anode. The phenomenon of focussing or convergence of the rays is due to these rays seeking the weakest part of the magnetic field. The field formed by the iron disc terminal outside the solenoid, together with that of the short solenoid, had two channels in which the field was weakest: one through the orifice at the centre of the iron terminal, the other around the periphery of this terminal.

It was to be expected that the Canalstrahlen could not be brought to convergence by this application of a longitudinal magnetic field. The phosphorescence of these rays remained unaffected.

PHOSPHORESCENCE OF THE CANAL RAYS.

In most cases the phosphorescence caused by the Canalstrahlen is similiar in color to that produced by the cathode rays. When, however, the Canalstrahlen fall upon lithium chloride, there seems to be a marked difference. Professor J. J. Thomson in his treatise on Conduction of Electricity through Gases[2] describes a form of tube in which a layer of lithium chloride can be bombarded alternately by both kinds of rays, and says that when the layer is struck by the Canalstrahlen it shines with a bright red light; the lines of the lithium spectrum are very bright, and when the direction of the discharge is reversed, so that the layer is struck by the cathode rays, its color changes from bright red to steely blue, giving only a faint continuous spectrum but not the lithium lines. The layer speedily becomes black in hydrogen.

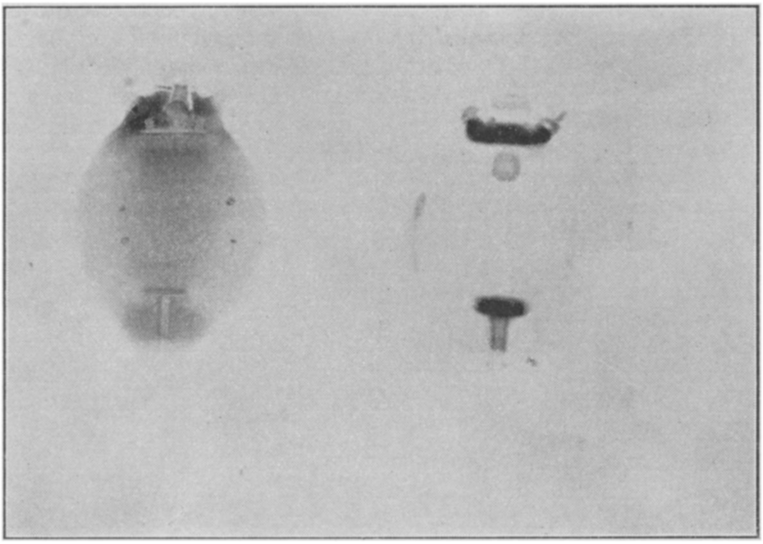

FIGURE 2.

---

[2] University Press, Cambridge, 1906, p. 642.

I have succeeded in producing the red phosphorescence by the cathode rays, thus annihilating the distinction, in this case, between the two kinds of rays. The method adopted seems to have a general application in the study of phosphorescence and is as follows:

The vacuum tube was of cylindrical form. Figure 1 shows the arrangement. A represents the circular iron terminal with its central orifice perforated by a glass tube; S, the solenoid; L, the ground-glass stopper with the layer of lithium chloride at its end.

When the solenoid is excited, the cathode rays can be brought to a sharp focus on the layer at L, and the apparatus can be called in popular language a magnetic lens. A very intense cathode beam can be made to converge at L by suitably adjusting the solenoid. The rays seek the weakest part of the magnetic field. Immediately on striking the layer of lithium chloride the red phosphorescence appears at the centre of the focus, and is surrounded by the blue phosphorescence; either the red or the blue can be produced at pleasure.

It seems, therefore, that if n is the number of cathode particles, m their mass, v their velocity, and n' the number of positive particles, m' their mass, v' their velocity, that the equation

$$nmv^2 = n'm'v'^2$$

holds on the unit of area, and that the distinction, in this case between the color produced by the cathode rays and the Canalstrahlen disappears. The production of the two colors is a question of energy on the unit of area.

I have examined the phosphorescence of the other metals of the same group as lithium chloride. Caesium chloride gives a very bright blue color for both the cathode and the canal rays, and the blue lines of the spectrum appear with the application of the cathode beam. Rubidium gives both a red and a blue color; the red, however, is much less bright than in the case of lithium chloride. All of these salts are quickly decomposed. Calcium tungstate recovers from fatigue very quickly, and is not decomposed appreciably, even after long exposures. Its use for X-ray screens is therefore substantiated by these experiments.

Application of a Longitudinal Magnetic Field to X-ray Tubes.

In the article on the Magnetic Field and Electric Discharges,[3] I stated that the application of a longitudinal field at the anode might form a useful method of concentrating the cathode rays. Since this article was written I have studied the subject more carefully, and have devised a safe and practical method, which is analogous to that I have used in the study of the phosphorescence of the Canalstrahlen.

---

[3] These Proceedings, **28**.

The form of tube is shown in Figure 1. A is an iron disc anode (Figure 3) with a perforation at its middle. S is a solenoid which can be adjusted along an appendix to the X-ray bulb. F is the usual focal plane of polished platinum. Opposite this focal plane the glass is blown thin to permit the egress of the X-rays. The cathode beam is brought to a focus at F by adjustment of the longitudinal field of the solenoid.

The dimensions of the apparatus are as follows :

Diameter of the spherical bulb, 10 cm. Distance between the concave aluminium cathode and the iron disc anode, 6 cm. Length of the cylindrical appendix containing the focal plane, 10 cm. Internal diameter of the cylindrical appendix, approximately 3 cm. The outer diameter of the solenoid was 10 cm., the internal diameter 6 cm. Length, 4 cm. There were 10 layers of no. 18 wire, Brown and Sharpe gauge. The solenoid was excited by two or five storage cells. A narrower appendix and a smaller bulb opposite the focal plane would give a stronger field with less current.

When the cathode stream is made to converge by the solenoid on the focal plane F, the intensity of the X-rays is increased in a marked manner. Judging the intensity by the distance at which equal intensity is obtained with and without the magnetic field, I have more than doubled the intensity of the X-rays by the application of the field. The method has the advantage of producing the X-rays from a sharp focus and should, therefore, give better definition.

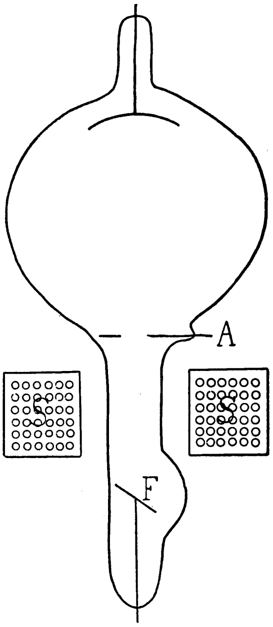

FIGURE 3.

It may be urged that the amount of energy employed in exciting the magnetic field could, with equal advantage, be added to that which excites the tube; but this would result in possible strain or danger to the tube and would not result in bringing the stream to a sharp focus. The large bulb need not be blown thin, and therefore the danger of perforation can be greatly lessened; moreover, the application of the magnetic field serves as a rectifier, and when a Leyden jar is used it allows only the oscillation from the cathode to reach the focal plane.

The canal rays appear to fatigue certain substances, — for instance, lithium chloride and rubidium chloride, — and after the application of these rays the blue phosphorescence of the cathode rays is diminished. It can, however, be restored by increasing the strength of the cathode beam. This can be accomplished by the following arrangement. A storage battery was connected to the exhausted tube through a large running water resistance, and a spark gap was inserted in the circuit. The coatings of a small Leyden jar were connected to the spark gap; the spark seemed continuous to the eye. Under the effect of the longitudinal magnetic field a very brilliant phosphorescence could be produced even after extreme fatigue of the group lithium, caesium, and rubidium chlorides. It is therefore probable that the cathode phosphorescence can be restored by stronger and stronger cathode rays condensed in the manner I have described.

Jefferson Physical Laboratory,
Harvard University.